

# **Characterizing the deep insular shelf coral reef habitat of the Hind Bank Marine Conservation District (US Virgin Islands) using the Seabed Autonomous Underwater Vehicle**

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## Abstract

The benthic communities of the deep insular shelf at the Hind Bank Marine Conservation District (MCD), an important spawning grouper aggregation site, were studied with the Seabed autonomous underwater vehicle (AUV) at depths between 32 to 54 m. Four digital phototransects provided data on benthic species composition and abundance of the insular shelf off St. Thomas, U.S. Virgin Islands. Within the western side of the MCD, well-developed coral reefs with 43% mean living coral cover were found. The *Montastrea annularis* complex was dominant at all four sites between 33 to 47 m, the depth range where reefs were present. Maximum coral cover found was 70% at depths of 38 to 40 m. Quantitative determinations of sessile-benthic populations, as well as the presence of motile-megabenthic invertebrates and algae were obtained. The Seabed AUV provided new quantitative and descriptive information of a unique coral reef habitat found within this deeper insular shelf area.

Keywords: Atlantic; U.S. Virgin Islands; Coral reef; Deep hermatypic corals; AUV

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## 1. Introduction

Shallow coral reefs in the tropical West Atlantic Ocean have experienced living coral cover declines of up to 80% in the last 30 years (Gardner et al., 2003). Pollution, sedimentation, hurricanes, and coral disease are all contributors to the decline in living coral cover. While numerous assessments of coral reef habitat have been conducted throughout the tropical western Atlantic and elsewhere using SCUBA, there is limited information on the deeper reefs zones, up to 100 m, which lie beyond the range of safe diving operations. Mapping and monitoring deeper hermatypic (zooxanthellate) coral reefs is necessary for selecting and protecting unique areas of high living coral cover, diversity, and structural complexity that could aid in the recovery of the shallower fish and benthic communities.

In the past, an evaluation of deep-water fish habitats and abundance around Puerto Rico and the U.S. Virgin Islands, at depths ranging from about 100 - 450 m, was conducted using the *Johnson-Sea-Link II* submersible (Nelson and Appeldoorn, 1985). To this day, the upper insular slope reefs of Puerto Rico and the Virgin Islands, found at intermediate depths (30-100 m), remain largely undescribed.

The Seabed autonomous underwater vehicle (AUV) is a new imaging platform designed for high resolution optical and acoustic sensing (Singh et al., 2004). The Seabed was tested over the insular shelf slope off southwestern Puerto Rico in March 2002 to a maximum depth of 125 m (Armstrong et al., 2002; Singh et al., 2004). This test dive established the potential of this new tool for mapping and characterizing the upper insular slope coral reef habitat.

During June 2003, we used the Seabed for imaging the benthic habitats of the shelf edge and upper insular slope of the Hind Bank Marine Conservation District (MCD), south of St. Thomas, U.S. Virgin Islands. The MCD is a non-fishing area that was established as per recommendation of fishers, scientists and government officials in 1999, to conserve and manage representative samples of marine habitats and ecosystems and to maintain marine biodiversity. The area was originally managed as a seasonal closure for the protection of the red hind (*Epinephelus guttatus*) spawning aggregation on the eastern side of the MCD. The spawning aggregation primary site was described by Beets and Friedlander (1997). The dominant coral present was flattened colonies of *Montastrea annularis*. More recently, a limited number of diver surveys at depths of 38-39 m were conducted by Nemeth et al. (2004).

Up to now, very little quantitative information has been available on the structure and composition of the coral reefs at the MCD due to the depth of these reefs. The goal of this study was to characterize the benthic community structure and biodiversity of these deeper insular shelf corals reefs. The Seabed high resolution color images were used to describe the major components of the

coral reef community of the MCD, which includes corals, gorgonians, sponges, other macro-invertebrates, and algae, and to quantify living coral cover, species richness, diversity, and evenness.

## 2. Study area

The Hind Bank MCD is located approximately 12 km south of St. Thomas, U.S. Virgin Islands at the shelf edge encompassing an area of approximately 41 km<sup>2</sup> (Figure 1). According to the bathymetry map of this area, depth ranges within the MCD from about 30 m on the western part to more than 430 m off the shelf edge. Within the insular shelf area of the MCD the maximum depth is approximately 62 m with an average depth of 42 m on the eastern half. Four, one-kilometer long transects were selected for the AUV surveys based on the known distribution of coral reef habitats and fish spawning grounds provided by previous SCUBA assessments. The two transects on the western side of the MCD were parallel to shore over areas dominated by coral reefs. The eastern transects were oriented perpendicular to shore at known fish spawning sites.

## 3. Materials and methods

The Seabed AUV is composed of two torpedo-like body sections fixed to each other with vertical structural members (Figure 2). The AUV was designed to operate up to 2000 m depth to carry out photo transects, side-scan sonar and bathymetric surveys. A Pixelfly 1024 x 1280 pixel resolution CCD camera, with 12 bits of dynamic range, is the primary optical imaging sensor. The camera was pointed straight down. A 150 watt-second strobe is used for photographic illumination. The strobe is mounted 1.4 meters aft of the camera to reduce the effects of lighting backscatter in the images (Figure 2a). The frequency of photos is a function of strobe recharge time (2.5 seconds). The size of the image was determined based on the altitude of the vehicle to the bottom and the field of view of the camera.

Measurements of velocity over the bottom, heading, altitude, pitch, roll, and integrated position are provided by a 300 kHz Acoustic Doppler Current Profiler (ADCP), which projects four sonar beams into the water. These are arranged in a Janus configuration pointing 30° fore, aft, to port and to starboard. We utilize the forward pointing beam for obstacle avoidance. A Paroscientific Model 8DP depth sensor provides depth information that, when combined with a dedicated vertical thruster, delivers depth accuracies in the order of 3.5 cm during our missions. More information on Seabed components, sensors, control systems, and navigation can be found in Singh et al. (2003).

The AUV, which runs at speeds between 0.3 m/s to 1 m/s, was programmed to run at minimum speed and to maintain a fixed distance from the bottom to avoid collisions in case sudden changes in bottom relief were

encountered. The distribution of the four thrusters, coupled with the passive stability of a two-hulled vehicle with a large meta-centric height (Figure 2b), allows the Seabed to survey close to the sea floor, even in very rugged terrain and to follow a greater than 45° slope. As opposed to most other AUV's, the Seabed was designed to be hover capable, that is, to be able to independently drive in the X,Y and Z axes.

Each transect was approximately 1 km in length and produced over 500 images, each about 3.1 m wide by 2.5 m long, at the predetermined 4 m distance from the bottom. The exact depth of each image was determined by combining the depth of the AUV (measured with the Paroscientific sensor) with its altitude (measured by the ADCP). The initial position of the vehicle at launch is determined by shipboard GPS with an accuracy of tens of meters.

Underwater imagery is typically characterized by low contrast and low color fidelity. The nonlinear attenuation of the visible spectrum in seawater causes parts of the visible spectrum to be preferentially attenuated. Thus most underwater images tend to be saturated in the blue-green region. We reprocessed the raw imagery to obtain three channel, 1280x1024x12bit RGB images. The 12 bits of dynamic range provided by the camera that is part of Seabed allow us to compensate and color balance the imagery as shown in Figure 3.

The enhanced benthic imagery was analyzed for percent cover of living corals and other benthic components using random points generated by the *Point Count for Coral Reefs* software (P. Dustan, personal communication). The clearest, best quality images (50-70 per transect) were selected and individually analyzed using 50 random points and the percent cover of corals, sponges, algae, and bare substrate was recorded. From images acquired within coral reef areas the diversity index for corals was calculated using the Shannon-Weaver Diversity index:

$$H' = - \sum P_i \ln P_i \quad (1)$$

where  $P_i = n_i / n$  and  $n$  = total number of coral colonies. Evenness was calculated using Pielou's evenness index:

$$J = H' / \ln H_{\max} \quad (2)$$

where  $H_{\max}$  = total number coral species.

#### 4. Results

At the western side of the MCD, the reef at PR-03 had a depth range from 33 to 42 m (Figure 4a) while at PR-04, the reef extended from 36 to 41 m in depth (Figure 4b). Higher depths were found at the eastern side of the MCD

1 where the transect lines were perpendicular to the coast and extended beyond  
2 the shelf edge. At PR-07 the reef was restricted to a narrow zone 45 to 47 m  
3 deep in a transect that exceeded 60 m in depth (Figure 4c). In a similar way, at  
4 PR-08 coral reefs were only present in the middle of the transect at depths from  
5 41 to 46 m (Figure 4d). In all cases the AUV followed the bottom contour  
6 maintaining a distance of approximately 4 m from the bottom. In addition to  
7 depth, bottom composition varied considerably between the east and the west  
8 transects of the MCD. Transects PR-03 and PR-04 were mainly composed of  
9 coral reef areas (97 and 100%, respectively), whereas transects PR-07 and PR-  
10 08 consisted of small coral reef patches separated by hardground areas along  
11 with algal mats, sand, and sparse seagrasses (Figure 5). Hardgrounds are low-  
12 relief areas where sediments have been lithified into rock. In these consolidated  
13 substrates sparse sponges, gorgonians and algae may be present. Algal mats are  
14 a dense layer of algae that blankets the bottom while “sand” refers to substrates  
15 of unconsolidated calcium carbonate grains. Seagrasses were only present  
16 within the algal mats and sand bottom categories. Within the reef areas, coral  
17 cover at PR-04 was significantly higher ( $p < 0.05$ ) than at the other three sites  
18 with coral cover ranging from 29 to 43% (Figure 6). Bare substrate was the  
19 second most important category, in terms of percent cover, within coral reefs  
20 areas, except for PR-03, where macroalgae was the dominant component.  
21 Macroalgae was characterized by green, brown, and red algae, while the bare  
22 substrate category includes dead coral colonies, uncolonized hard-bottom and  
23 sand.

24  
25 Within the scleractinian cover composition, the image data analysis  
26 revealed dominance by *Montastrea annularis* complex at all transects, but  
27 particularly at PR-03 (Figure 7) where the average cover of *M. annularis* was  
28 about 90% and this dominance was nearly constant with depth. At PR-04 the  
29 reef was also highly dominated by the *M. annularis* complex but with  
30 increasing cover of the genus *Agaricia* with increasing depth (Figure 8). The *M.*  
31 *annularis* complex was less dominant at PR-07 (Figure 9) at around 50-63% of  
32 the total coral cover. The least dominance of this species was found at 46 m in  
33 PR-08 where its coverage was reduced to less than 40% and the genus *Agaricia*  
34 covered up to 30% of the substrate (Figure 10). Overall, *Montastrea annularis*  
35 complex was the dominant coral species representing 92% of the coral cover.  
36 One-Way ANOVA showed statistical differences in coral cover among depths  
37 at PR-03 and PR-04 ( $p = 0.0006$  and  $p = 0.005$ , respectively), but no significant  
38 differences were found at PR-07 and PR-08 ( $p = 0.138$  and  $p = 0.194$ ,  
39 respectively).

40  
41 The relatively small Index of Diversity (range 1.48 to 1.85, Table 1)  
42 further validates the dominance of the *M. annularis* complex over the rest of the  
43 species. Species richness was highest on the western side of the MCD with 14  
44 identifiable coral species at PR-04 followed by 11 at PR-03. On the eastern side  
45 of the MCD, the coral reef at PR-07 and PR-08 consisted of only seven and nine  
46 coral species, respectively (Table 1).

1  
2 Within coral reef and hard ground areas, the benthic cover of other  
3 macro invertebrates was dominated by sponges and gorgonians at all sites  
4 (Table 2). The most dominant sponges were the giant barrel (*Xestospongia*  
5 *muta*) and rope sponges of the genus *Aplysina*. A total of 17 species of sponges,  
6 two hydrozoan corals (*Millepora* sp.), 10 gorgonians, one black coral  
7 (*Cirrhopathes* sp.), and four lobster and crab species (crustaceans) could also be  
8 identified in association with coral reef and hardground substrates. Most  
9 gorgonian species were found in the western part of the MCD at PR-03 and PR-  
10 04. The only invertebrates associated with sand bottom and algae substrate that  
11 could be identified from the images were two species of conch (genus  
12 *Strombus*), three species of echinoderms, and the upside-down jellyfish  
13 *Cassiopea*. The echinoderms consisted of the sea urchin *Meoma ventricosa* and  
14 two species of sea cucumbers (holothurians). Seven algae and one seagrass  
15 species were identified in the phototransects (Table 3). Only functional groups  
16 could be reported for most algae except for *Udotea cyathiformis* and *Halimeda*  
17 sp. that could be distinguished due to their characteristic shape and were only  
18 found in the eastern side of the MCD. Turf algae are a multispecific assemblage  
19 of filamentous algae. The seagrass *Halophila baillonis* was found in sand  
20 bottoms and algal substrates at both PR-07 and PR-08.

## 21 22 **5. Discussion**

23  
24 The geomorphology of the eastern side of the MCD, as depicted by the  
25 AUV transects, follows the description of Olsen and LaPlace (1978) who  
26 described the red hind spawning site with the bottom topography as a series of  
27 coral ridges, parallel to the 100 fathom (182 m) curve. These ridges were  
28 usually 100 m across and separated by calcareous sand which ranged from 50 to  
29 300 m in width, with the dominant coral, *Montastrea annularis*, measuring less  
30 than 1 m in diameter. From a series of SCUBA dives at the red hind spawning  
31 site along the shelf edge reef, at depths of 38-48 m, Clavijo and Tobias (1985)  
32 described the substrate as dominated by dense scleractinian cover, primarily  
33 plates of *Montastrea annularis*. Nemeth (2003) reported *Montastrea franksi* as  
34 the dominant species in the MCD and within the spawning aggregation site.

35  
36 The *Montastrea annularis* species complex is composed of the sibling  
37 species *M. annularis*, *M. faveolata*, and *M. franksi* (Weil and Knowlton, 1994),  
38 which are the dominant reef building corals in the tropical Western Atlantic  
39 (Goreau, 1959). While the *M. annularis* complex represented 20% to 60% of  
40 the corals found in near shore and mid-shelf reef areas in depths of 5 to 25 m  
41 (Herzlieb et al., in press), it dominated in 30 to 40 m depths with cover ranging  
42 from 60 to nearly 100%. In areas deeper than 40m it still represented 50 to 60%  
43 of the coral cover. Also common in deep reef areas of the Caribbean are several  
44 species of the genus *Agaricia* (Lang, 1974; Reed, 1985; Liddell and Ohlhorst,  
45 1988). Within the MCD, *Agaricia* sp. represented up to 10% of the coral cover  
46 at depths less than 41 m and over 20% of the cover in depths greater than 45 m.

1 The *M. annularis* complex and *Agaricia sp.* both grew as plate-like formations.  
2 The plate-like morphology is an adaptation to reduced sunlight at deeper depths  
3 (Grauss and Macintyre, 1982). *Porites astreoides* and *Mycetophyllia sp.* were  
4 found at all depths between 33 m and 47 m. *Agaricia sp.* was only found in  
5 small colonies that were easily identified by their spiraling ridge pattern and  
6 brownish color. The average living coral cover seen in the photo transects was  
7 43% with maximum cover of 70% found in some areas at 40 m. Also found in  
8 abundance was an encrusting sponge, which is most likely *Cliona sp.* This  
9 sponge accounted for 96% of all the sponges found, while most of the other  
10 sponges present were columnar. *Cliona* is a brown-black sponge that grows  
11 over corals as it dissolves them, which may account for the high percentage of  
12 bare substrate.

13  
14 In Bermuda, most deep-water hermatypic corals grow on reef substrate  
15 down to 60 m (Fricke and Meischner, 1985). The coral growth in the deeper  
16 reef areas in Bermuda appeared to be controlled by macroalgae growth. In the  
17 Bahamas, coral assemblages less than 30m depth represented 3 to 25% of  
18 benthic cover and were dominated by *Agaricia agaricites*, *M. cavernosa*, *M.*  
19 *annularis*, *P. astreoides*, and *P. porites* (Liddell et al., 1997). The deeper (30-50  
20 m) coral assemblages represented less than 3% of the benthic cover and were  
21 dominated by *M. cavernosa* and *Agaricia spp.* (Liddell et al., 1997). Low water  
22 temperatures favor macroalgae growth leading to a reduction of coral growth  
23 (Johannes et al., 1983). In the fore-reef slope of Jamaica, the flattened growth  
24 form of *M. annularis* is the dominant species of coral above 45 m (Goreau and  
25 Land, 1974).

26  
27 At a study site close to the PR-07 transect in this study, Nemeth et al.  
28 (2004) reported mean values of 28% living corals, 35% macroalgae, 20% dead  
29 coral with turf algae, 7% sand/sediment, 4% sponges, and 0% gorgonians. This  
30 compares favorably with the AUV estimates of living coral (29%) and sponges  
31 (3.8%) at PR-07. The bare substrate category was 28.5%, coralline algae  
32 (16.6%), macroalgae (21.2%), and gorgonians (1%). In a separate study,  
33 Herzlieb et al. (in press) found coral cover on the western end of the MCD to be  
34 44.8% with coral cover of the *M. annularis* complex near 80%. Nemeth et al.  
35 (2004) also reported dominance by the *M. annularis* complex at 76% of total  
36 living coral cover, a 1.4 diversity index, coral bleaching at 6.5% and incidence  
37 of diseased corals at 1.4%. The present study could not detect any evidence of  
38 coral disease in any of the photo transects and at PR-07, the diversity index was  
39 1.8 with dominance of *M. annularis* complex at 50-60%. The reefs at PR-07 are  
40 substantially deeper (45-47 m) than the reef area described by Nemeth et al.  
41 (2004) at 38-39 m. This could account for the observed differences in some of  
42 these coral reef parameters.

43  
44 Although the coral reefs of the MCD are largely unknown, they appear  
45 to be relatively undisturbed by anthropogenic factors due to the considerable  
46 distance to land sources of runoff and pollution (Herzlieb et al., in press). Their



greater depth also protects them from wave damage from storm surge. Intermediate depth coral reefs, such as those of the MCD, could serve as refugia for shallow water species in times of environmental stress (*sensu* Riegl and Piller, 2003).

The high coral cover throughout the MCD suggests that these reefs are largely unaffected by natural and human disturbances. Since the late 1970's, hurricanes (Woodley et al., 1981; Edmunds and Witman, 1991) and disease (Gladfelter, 1982) have devastated shallow water reef communities throughout the Caribbean. Edmunds and Witman (1991) reported that Hurricane Hugo destroyed over 33% of the live cover of *M. annularis* on shallow (10 m) reefs off St. John, US Virgin Islands. Although the turbulence from large hurricane waves can cause fragmentation and abrasion damage in many shelf edge reefs, these effects are limited to depths of 30 m (Blanchon and Jones, 1997). The relatively high depths present at the MCD protects these coral reefs from the high turbulence generated by hurricane waves, since the minimum depth of the surveyed reefs was 33 m and most reefs were present at depths of 40 m or more. Recently, the mortality rate of shallow water corals in the Caribbean has increased dramatically due to a variety of diseases (Richardson et al., 1998a,b; Harvell et al., 1999). Although no disease was evident in the Seabed AUV digital imagery, Nemeth et al. (2004) reported that low levels of disease occurred within the MCD in spring 2003, but higher levels of disease (over 10%) occurred on similar deep reefs outside the MCD. They speculated that the unprotected deep reefs may have higher incidence of disease due to commercial fish traps, which not only injure corals but may act as vectors of disease when fishermen transfer traps from shallow to deep reefs.

There are numerous reports in the literature describing intermediate depth coral reefs (30-50 m) present in the deep fore-reef and upper insular slopes of many Caribbean Islands. However, the coral reefs of the MCD described here are present within the deeper zones of the insular shelf, a unique habitat that has not been described elsewhere. The distribution and characterization of similar habitats at other locations needs to be established before meaningful comparisons with similar coral communities can be made.

In summary, the quantitative characterization of benthic communities associated with the deep coral reef habitats of the MCD, as provided by the four AUV phototransects, compares favorably with the available information from previous diving surveys in this area. In most cases, the resolution of the Seabed digital imagery was adequate to identify the organisms to the species level. In other cases, only genera could be identified, and for most of the algae, only major groups could be identified. This study demonstrates that the high quality digital imagery provided by the Seabed AUV can be used to characterize the deeper zooxanthellate coral reef habitat present at depths greater than 30 m, which for most areas of the world, remain largely unknown. Quantitative

determinations of sessile-benthic populations, as well as the presence of motile-megabenthic invertebrates and algae were obtained.

Our initial results show that the deeper reefs of the MCD are largely unaffected by hurricane disturbances, human impacts, and disease. Therefore, they could serve as a potential refuge areas and a source of larvae for the recovery of shallower coral reef communities present downstream and may play a critical role in the reestablishment of fish populations in adjacent insular shelf areas.

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**Figure Captions:**

1. Map of the Hind Bank MCD. The location of the MCD in relation to Puerto Rico and the U.S. Virgin Islands is indicated by an arrow. Corner coordinates are (A) 18°13.2'N, 65°06'W; (B) 18°13.2'N, 64°59'W; (C) 18°10.7'N, 65°06'W; (D) 18°11.8'N, 64°59'W. (Federal Register 64 (213): 60132-60133; November 4, 1999) (50 CFR Part 622 §622.33 (b) (1)).
2. The Seabed AUV: (A) schematic diagram of the major components, and (B) external view.
3. The reef at a depth of 40 m at PR-04 before (A) and after (B) color enhancement. Scale bar = 1 m.
4. a-d. Depth profiles of the AUV transects: (a) PR-03, (b) PR-04, (c) PR-07, and (d) PR-08. The box in (c) and (d) indicate where the coral reef was located within the transect. The reef was continuous over the entire transect in (a) and (b).
5. Percent distribution of various bottom types along the four transects
6. Bottom composition within the coral reef areas of each transect. Bare substrate category includes dead coral colonies, uncolonized hard-bottom and sand.
7. Coral cover by species and depth at PR-03.
8. Coral cover by species and depth at PR-04.
9. Coral cover by species and depth at PR-07.
10. Coral cover by species and depth at PR-08.

<b>Transect</b>	<b>Species Richness</b>	<b>Diversity Index (H')</b>	<b>Evenness (J)</b>
PR-03	11	1.48	0.615
PR-04	14	1.73	0.655
PR-07	7	1.85	0.949
PR-08	9	1.50	0.684

Table 1: Species richness, diversity and evenness at the four transects.

Group/Scientific Name	PR 03		PR 04	PR 07				PR 08			
	CR	HG	CR	CR	HG	AM	SA	CR	HG	AM	SA
<b>PORIFERA</b>											
<i>Cliona</i> sp.	+	+	+	+							
<i>Aplysina cauliformis</i>			+					+			
<i>Aplysina archeri</i>	+										
<i>Aplysina</i> sp.	+	+	+	+	+			+	+		
<i>Chondrilla nucula</i>		+									
<i>Diplastrella</i> sp.		+	+	+	+			+			
<i>Agelas clathrodes</i>	+	+	+	+	+			+	+		
<i>Agelas conifera</i>		+	+	+	+			+	+		
<i>Geodia neptuni</i>		+	+	+	+			+	+		
<i>Amphimedon compressa</i>	+			+	+			+	+		
<i>Pseudoceratina crassa</i>			+					+	+		
<i>Mycale laevis</i>			+					+			
<i>Xestospongia muta</i>			+	+	+			+	+		
<i>Neofibularia nolitangere</i>				+							
<i>Cinachyra</i> sp.									+		
<i>Cribochalina vasculum</i>								+	+		
<i>Strongylacidon</i> sp.								+			
<b>CNIDARIA</b>											
<b>Hydrozoans</b>											
<i>Millepora squarrosa</i>		+									
<i>Millepora alcicornis</i>			+					+	+		
<b>Scyphozoa</b>											
<i>Cassiopea</i> sp.							+				
<b>Gorgonacea</b>											
<i>Plexaura</i> sp.		+	+								
<i>Ellisella barbadensis</i>	+				+			+			
<i>Pseudopterogorgia</i> sp.	+		+		+						
<i>Plexaurella nutans</i>	+		+						+		
<i>Plexaurella</i> sp.	+		+						+		
<i>Gorgonia</i> sp.	+		+	+							
<i>Eunicea</i> sp.	+		+		+						
<i>Leptogorgia hebes</i>	+			+							
<i>Pseudoplexaura</i> sp.			+	+							
<i>Muriceopsis</i> sp.									+		
<b>Antipatharia</b>											
<i>Cirripathes</i> sp.			+					+	+		
<b>ECHINODERMATA</b>											
<i>Eostichopus</i> sp.							+		+		
<i>Holothuria</i> sp.							+				
<i>Meoma ventricosa</i>											+
<b>ARTHROPODA</b>											
<i>Scyllarides aequinoctialis</i>					+						
<i>Panulirus argus</i>					+				+		
<i>Palinurellus guandlachi</i>	+										
<i>Mithrax</i> sp.			+					+			
<b>MOLLUSCA</b>											
<i>Strombus gigas</i>							+				+
<i>Strombus costatus</i>											+

Table 2: Macro invertebrates (other than Scleractinians) identified in the phototransects (CR = Coral Reef, HG = Hardground, AM = Algal Mat, SA = Sand Bottom + Algae).



	PR 03		PR 04	PR 07				PR 08			
Group/Scientific Name	CR	HG	CR	CR	HG	AM	SA	CR	HG	AM	SA
<b>CYANOBACTERIA</b>					+	+					
<b>ALGAE</b>											
Brown algae	+	+	+	+	+	+		+	+	+	
Red algae						+		+		+	
Red coralline algae	+	+	+	+	+			+	+		
Green algae			+	+	+						
<i>Udotea cyathiformis</i>						+	+		+	+	+
<i>Halimeda</i> sp.					+	+	+	+	+		
Turf algae	+	+	+	+	+			+	+		
<b>ANGIOSPERMAE</b>											
<i>Halophila baillonis</i>						+	+			+	+

Table 3: Plants identified in the phototransects (CR = Coral Reef, HG = Hardground, AM = Algal Mat, SA = Sand Bottom + Algae).

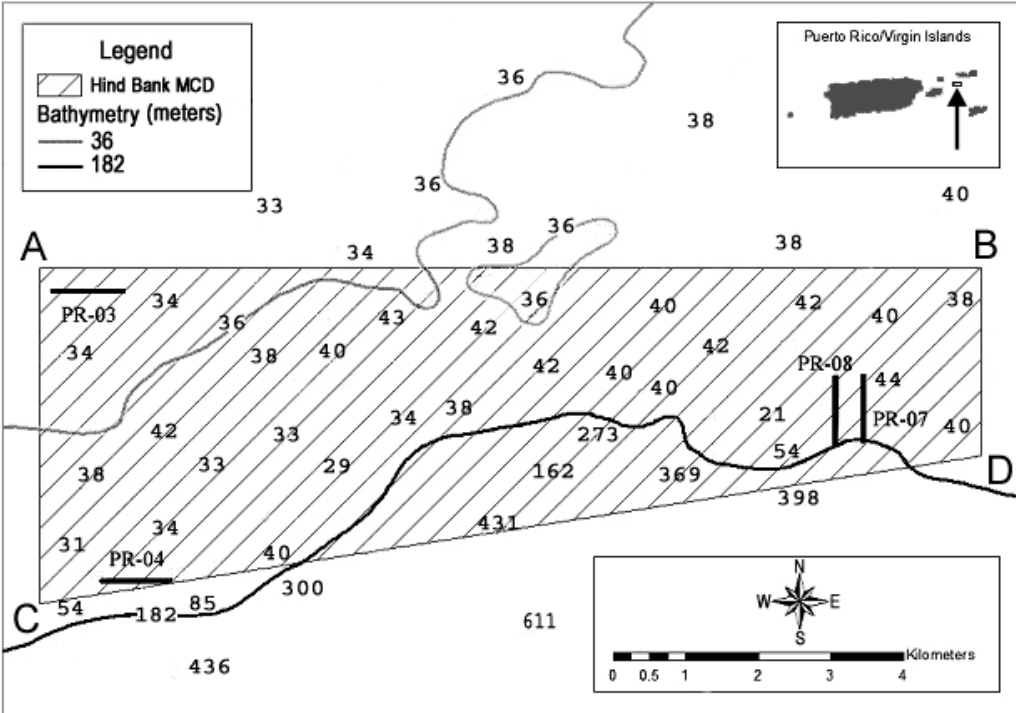
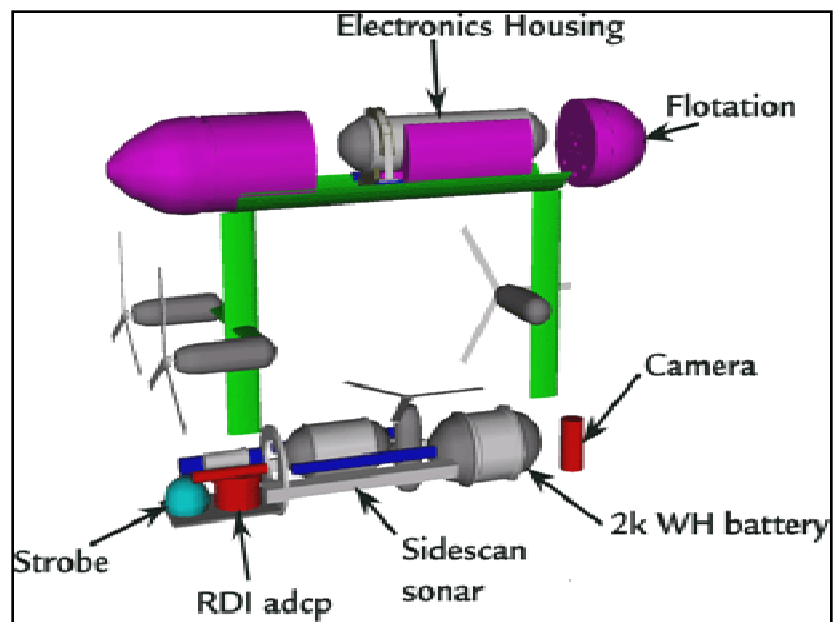


Figure 1

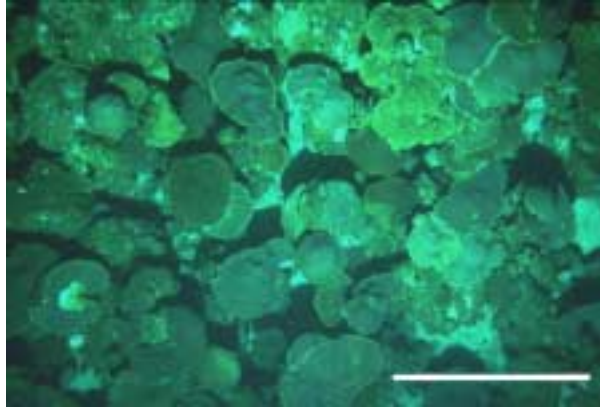


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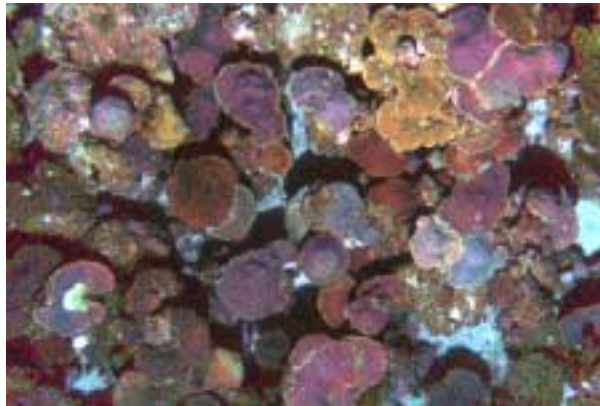


B

Figure 2



A



B

Figure 3

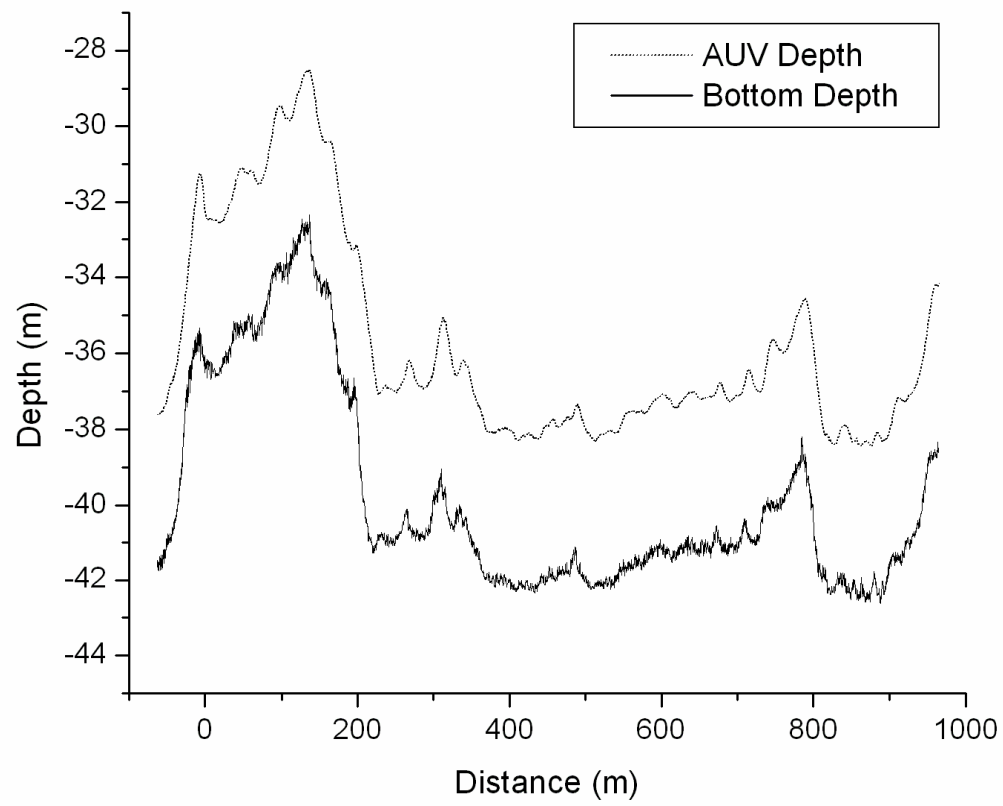


Figure 4a

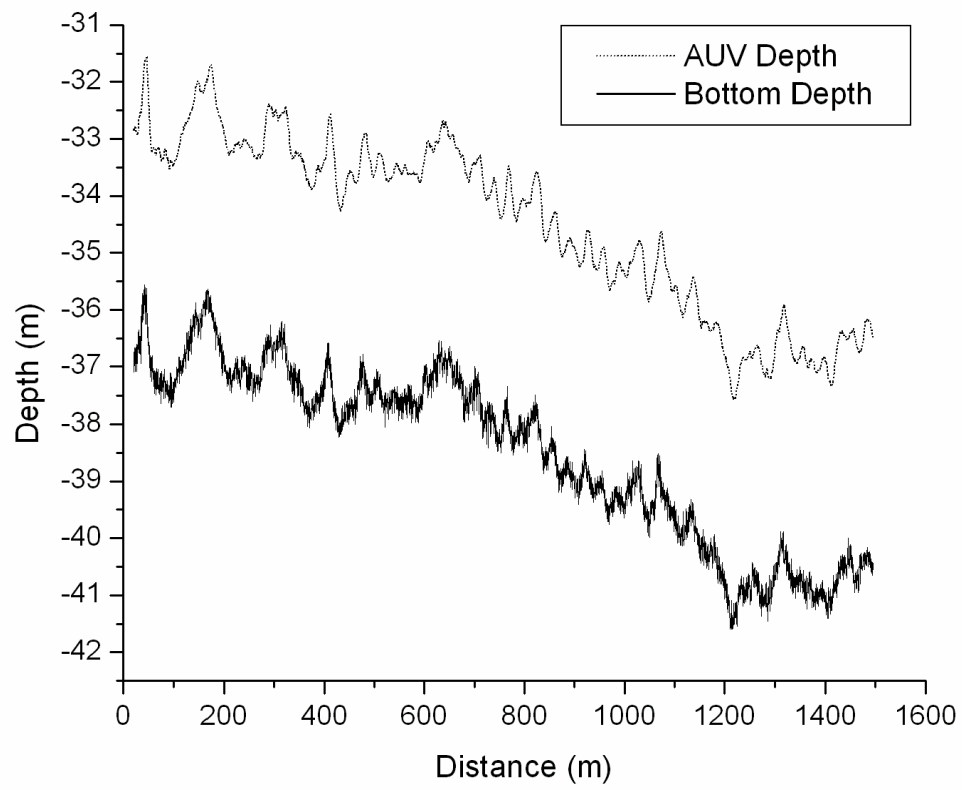


Figure 4b

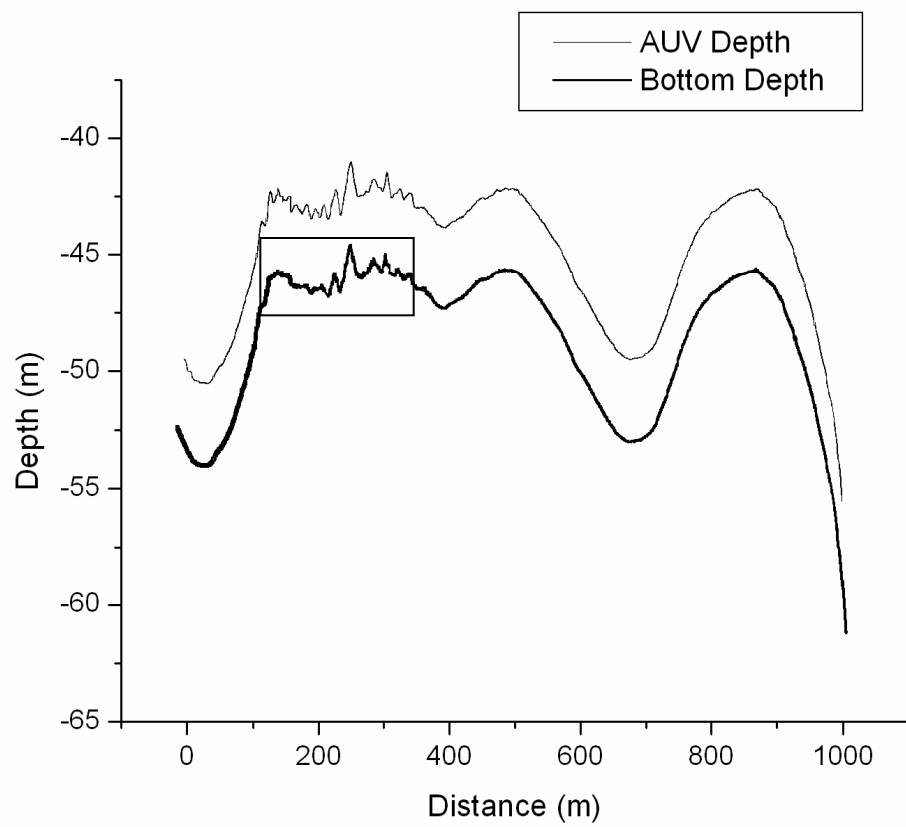


Figure 4c

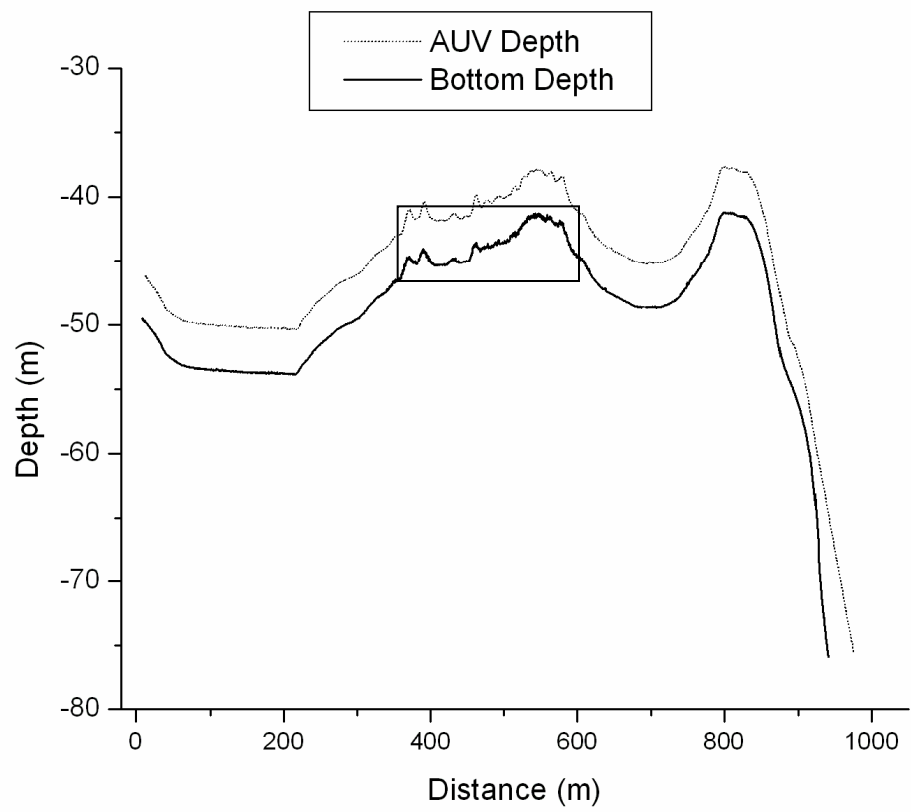


Figure 4d



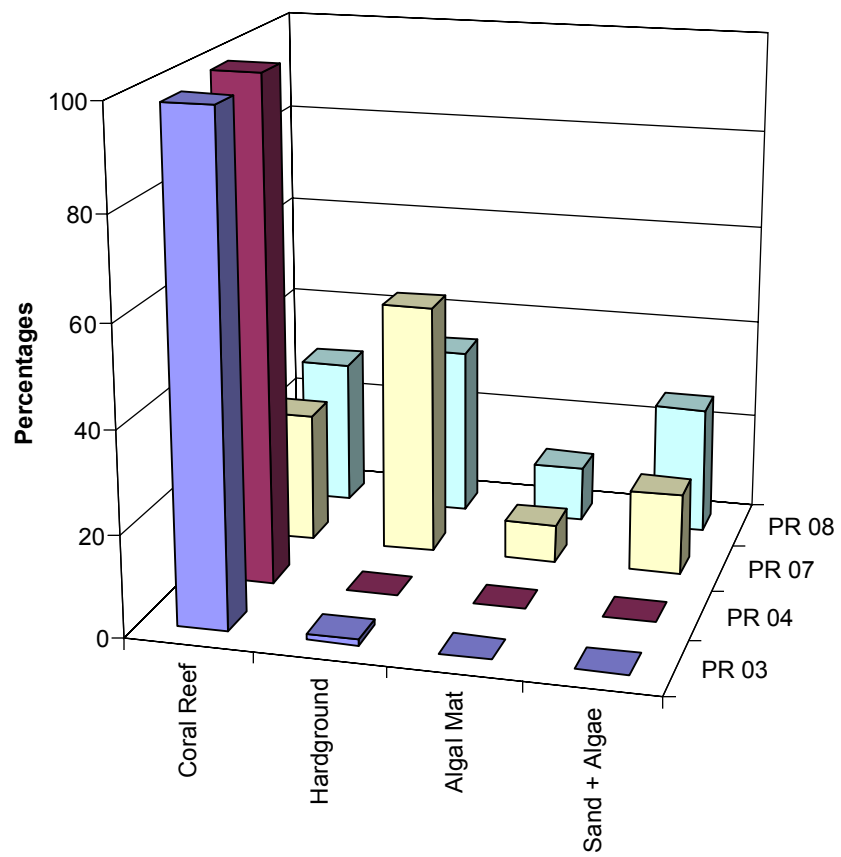


Figure 5.

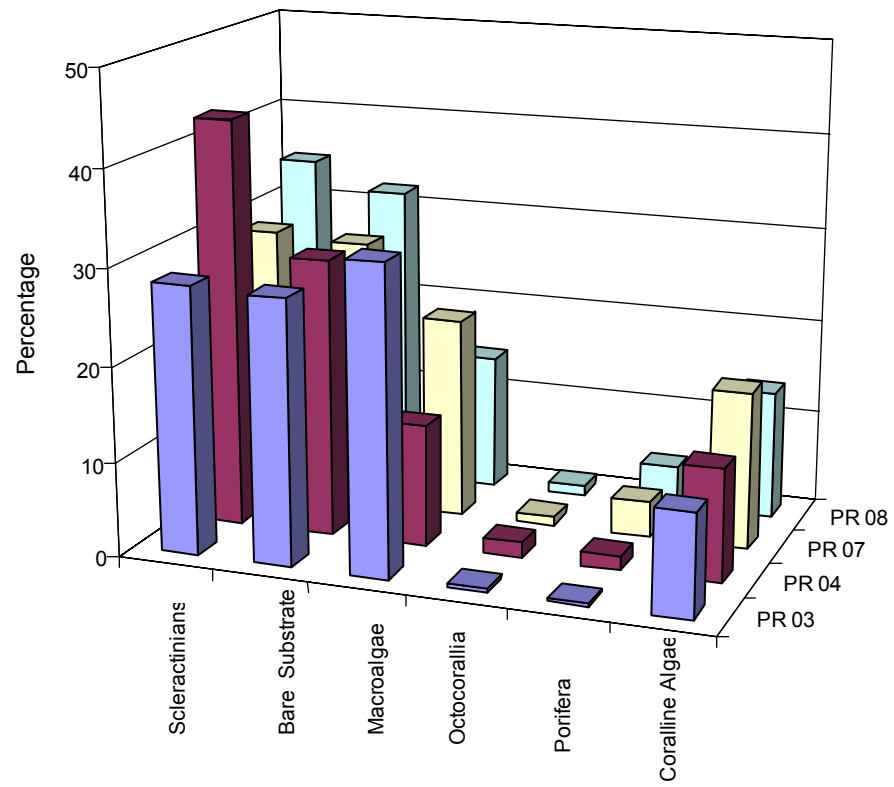


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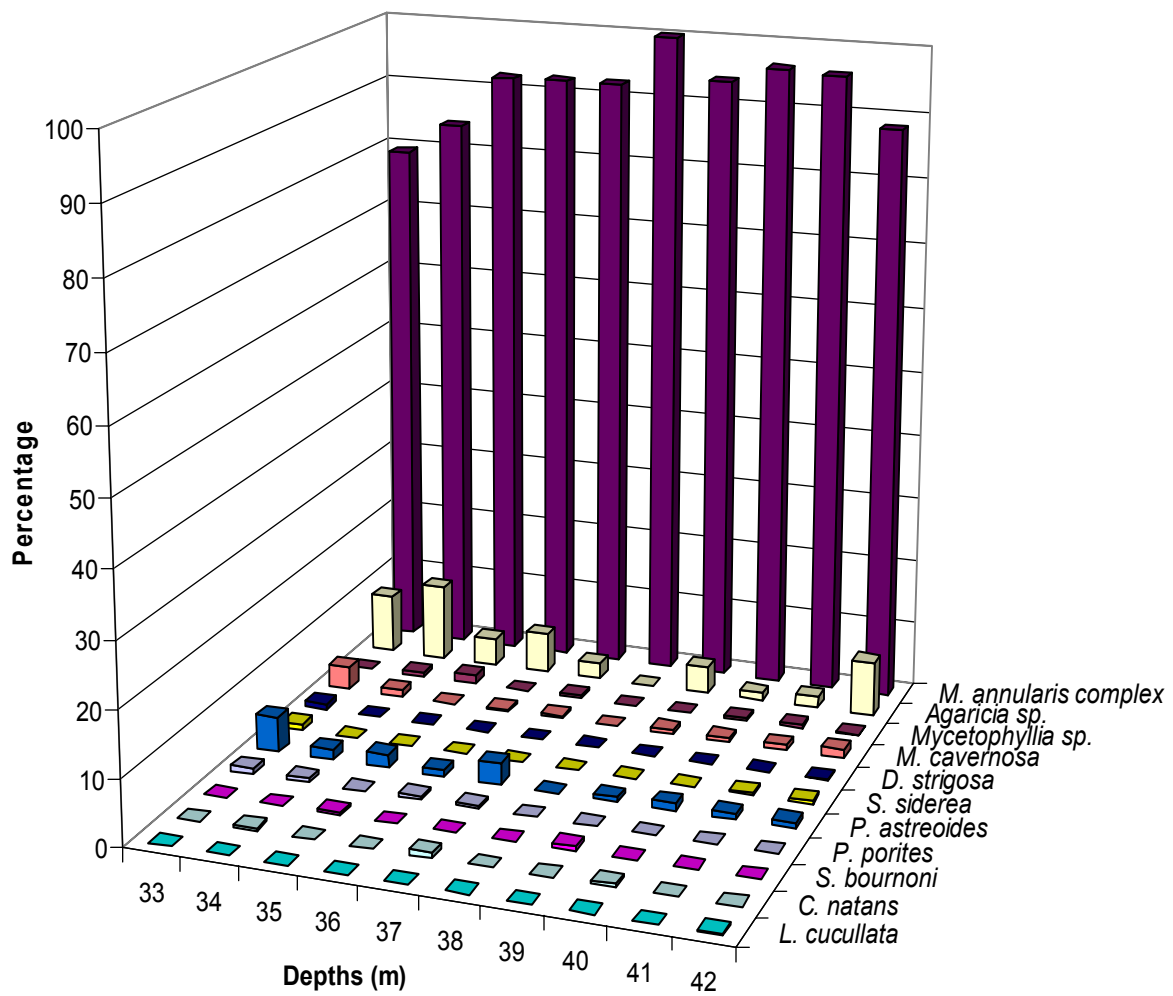


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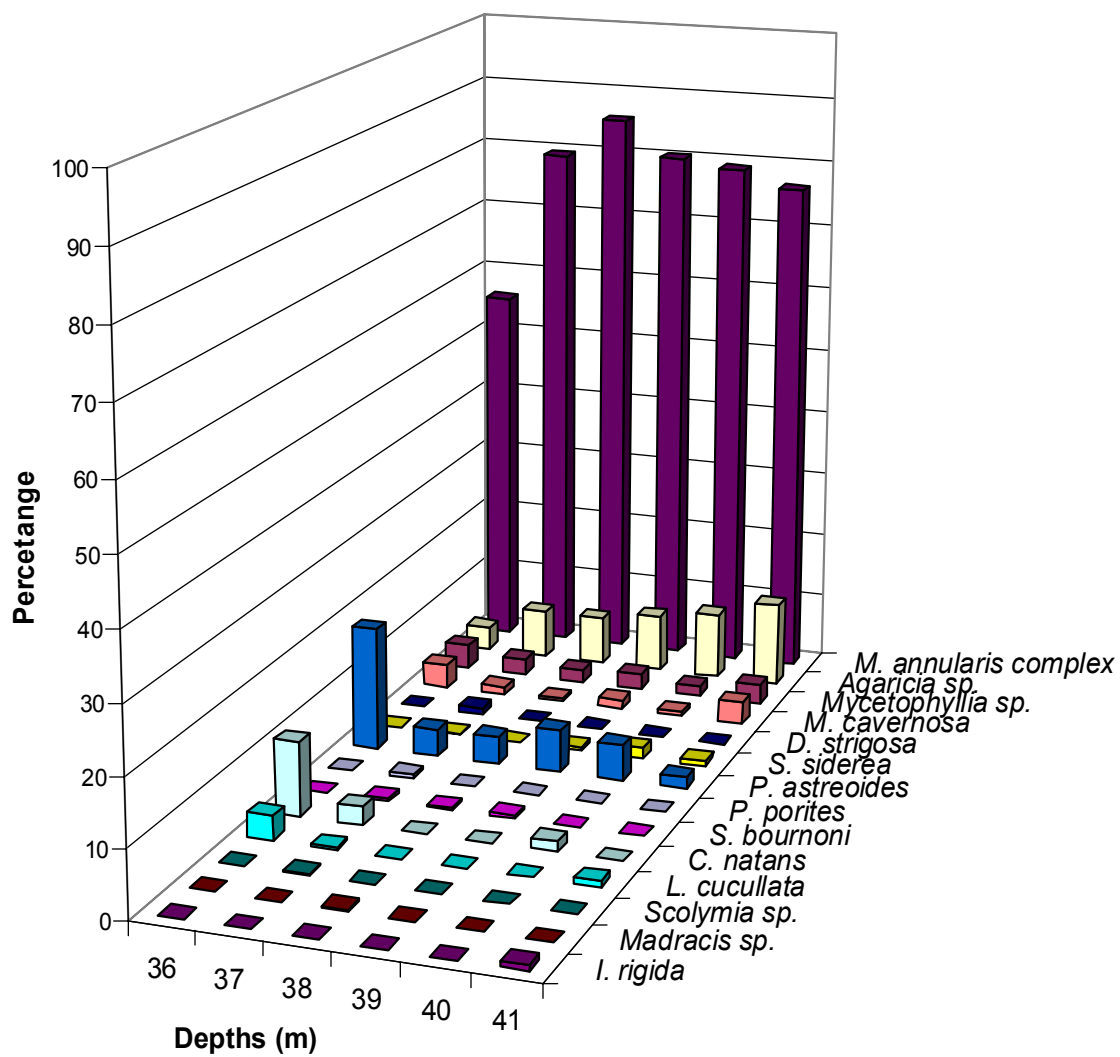


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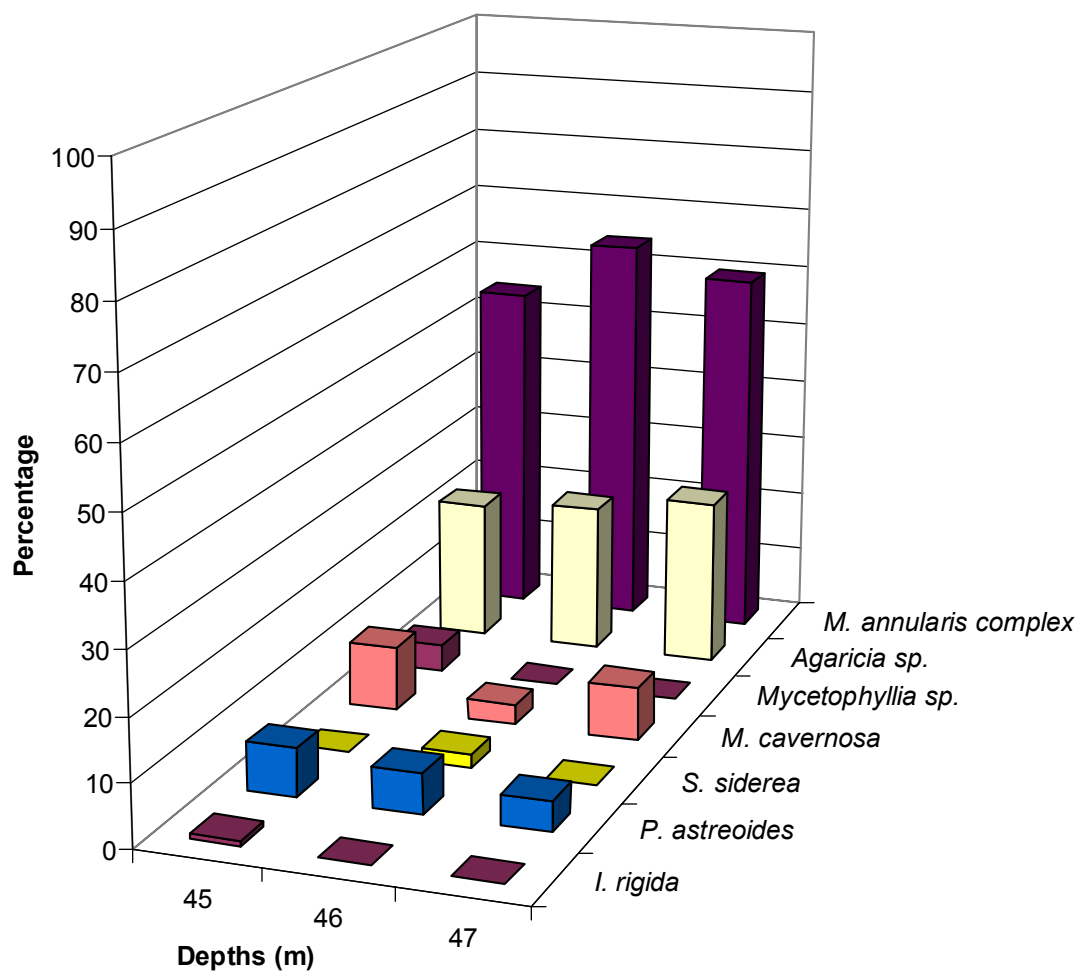


Figure 9.

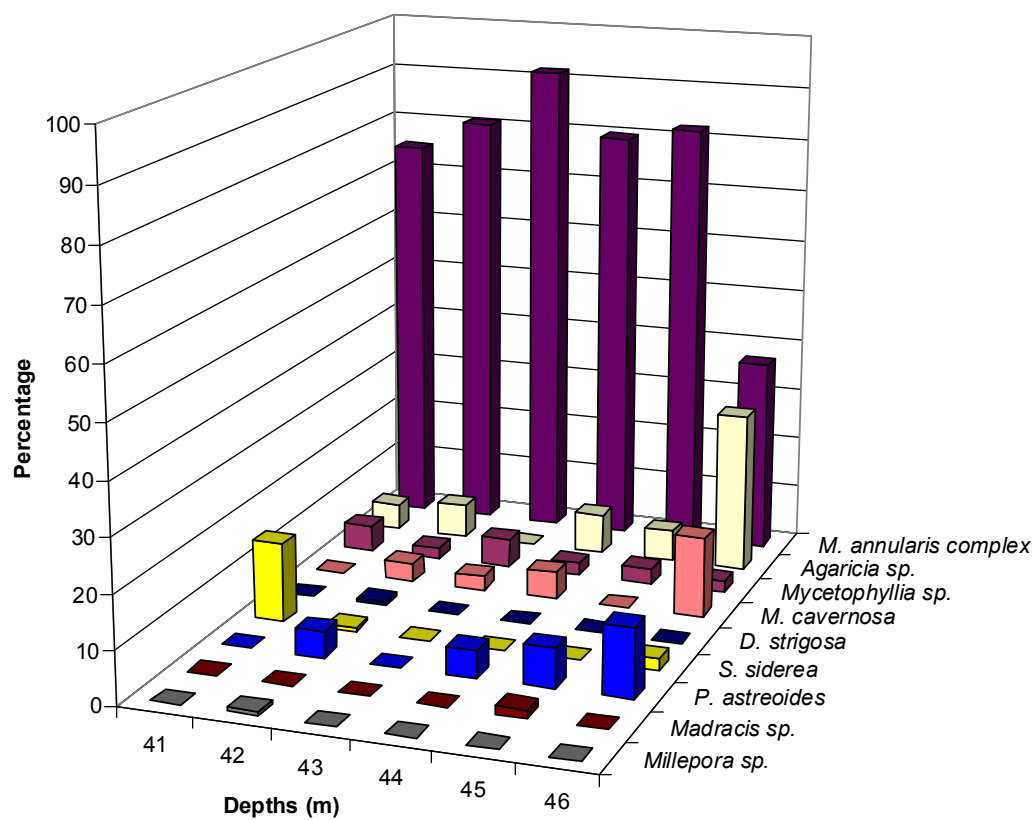


Figure 10.